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Center for Evaluation of Clean Energy Technology

Test Specification – Evaluation of Storage-Assisted Recharging Unit

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(CECET)**

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1 Objective

The objective of this Test Specification is to provide a method for testing a storage-assisted DC Level 2 electric vehicle supply equipment unit (aka DCFC), referred to in this document as a storage-assisted recharging (StAR) unit, for reducing power and energy requirements from the electrical grid of vehicles participating in the Advanced Vehicle Testing and Evaluation (AVTE) program or in other advanced vehicle testing. The purpose of this Test Specification is to identify testing methodology for StAR units capable of reducing the peak power and energy for installation and operation. This Test Specification outlines the methods for experimental conduct. The actual specific steps for the test conduct are listed and described in the associated Center for Evaluation of Clean Energy Technology (CECET) internal Work Instruction document.

2 Test Conduct

Documentation resulting from usage of this Test Specification shall be consistent, easy to understand, easy to read, and readily reproducible. All documentation required to complete testing shall be completed, approved, and ready for issue prior to commencing the testing it addresses. The following will abide by company policy:

- Review and approval of test results
- Storage and retention of records during and following testing activities
- Recording of any deviation from the outlined procedures and the reason for the deviation

3 Initial Conditions & Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items should be verified.

3.1 Personnel

Personnel conducting testing under this Test Specification, i.e., the Test or Project Engineer(s), shall be familiar with the requirements of this Test Specification, shall be trained in accordance with company policy, and shall be certified by a Mandated Reviewer prior to commencing any testing activities. This requirement includes training in all aspects of the Test Specification, including its automatic shutdowns and safety procedures.

3.2 Test Environment

All units to be tested shall be installed and operated outdoors. Testing shall take place under normal, random environmental conditions within the specifications for that unit. Any failure deemed to be caused by environmental conditions within the specification of the unit shall be reported as such.

3.3 Instrumentation

3.3.1 All instrumentation used during testing shall be calibrated. The calibration shall be performed and documented in accordance with company policy.

3.3.2 All instrumentation shall have the accuracies and resolutions noted. Unless specific exceptions have been made by a Mandated Reviewer, the following identifies the minimum instrumentation specification that shall be installed and employed during the testing.

3.3.2.1 Temperature

The temperature indicating devices must have a resolution of 2 °F (1 °C) and an accuracy of ± 2 °F (± 1 °C). The sensing element shall be shielded from radiant heat sources.

3.3.2.2 DC Current

Accuracy requirement is $\pm 1\%$ or better of total measurable range.

3.3.2.3 DC Voltage

Accuracy requirement is $\pm 1\%$ or better of total measurable range.

3.3.2.4 AC Metering

ANSI C12.20 Class .5 or better.

4 Test Activity Requirements

This section addresses the activities required to meet the stated purpose and objectives of this Test Specification.

The following data shall be collected during conduct of the tests specified by this document.

- 4.1.1 DCFC Output
 - 4.1.1.1 DC current
 - 4.1.1.2 DC voltage
 - 4.1.1.3 Ambient Temperature
- 4.1.2 StAR Battery
 - 4.1.2.1 DC current
 - 4.1.2.2 DC voltage
 - 4.1.2.3 Pack temperature
- 4.1.3 Grid Output
 - 4.1.3.1 AC power (reactive and real)
 - 4.1.3.2 AC energy
 - 4.1.3.3 Power factor
- 4.1.4 Vehicle
 - 4.1.4.1 Vehicle Energy Indicator (VEI), before and after charge

4.2 Collected Test Data

The following data should be collected, if available, during conduct of the tests specified by this document.

- 4.2.1 DCFC Output
 - 4.2.1.1 Pertinent vehicle- charger interface information
- 4.2.2 StAR Battery
 - 4.2.2.1 Minimum cell voltage
 - 4.2.2.2 Maximum cell voltage
 - 4.2.2.3 Minimum cell temperature
 - 4.2.2.4 Maximum cell temperature
 - 4.2.2.5 Manufacturer-defined SOC
 - 4.2.2.6 Manufacturer-defined State-of-Health (SOH)
 - 4.2.2.7 Cell balancing indicator
- 4.2.3 Grid Output
 - 4.2.3.1 Total harmonic distortion (THD)

4.2.3.2 RMS current, all phases

4.2.3.3 RMS line-to-line voltage

4.3 Characterization Testing

The purpose of this section is to outline tests that will characterize how the unit under test (UUT) operates and gather performance metrics.

CAUTION: All personnel who will conduct charging operations shall be specifically trained in all aspects of the charger, including its automatic shutdowns and safety procedures.

4.3.1 Characterization Test Preconditions

4.3.1.1 All tests shall be performed with a vehicle of the same year, make, and model.

4.3.1.2 Vehicle shall contain a traction battery with a rated energy greater than or equal to 16 kWh.

4.3.1.3 All tests shall start and end with a fully charged StAR battery.

4.3.1.4 If configurable, the power demand charge threshold shall be set to 20 kW or to the lowest possible AC power setting.

4.3.1.5 Vehicles used to test shall be discharged to 10% or less of the VEI subsequent to a full charge.

4.3.2 Performance Tests

4.3.2.1 Single-Charge Test

Charge one vehicle until full (or the current stops being delivered), then allow the StAR battery to fully recharge. This may require time-of-use¹ (TOU) functions to be turned off, allowing the StAR battery to recharge immediately after vehicle charging ceases. From the resultant data, determine how the StAR battery energy is utilized and characterize how it recharged in terms of current and voltage profiles.

4.3.2.2 Consecutive Charges

Charge vehicles consecutively² until the UUT de-rates the maximum output power from the DCFC shown in the Single Charge Test. If possible for this test, the UUT should be configured so that the StAR battery is not recharged while switching vehicles or if the total power drops below the power demand charge threshold³.

4.3.2.3 Single Charge Test with StAR Battery Disabled (if possible)

¹ Time-of-use functions are windows that can be setup to recharge the StAR battery at a preferred time to avoid higher electricity rates.

² If insufficient vehicles of the same year, make, and model are available to discharge the StAR battery to the point that the output power is de-rated, other vehicle types may be substituted at the Mandated Reviewer's discretion. The study must include no fewer than two vehicles.

³ Some units may charge the StAR battery at a rate that equals the power demand charge threshold when summed with the needed AC power to charge the vehicle battery.

Disable the StAR battery so that only grid power is used, then charge one vehicle until full (or current stops being delivered). If the input AC power or output DC power level is also configurable, set the value to the power demand charge threshold for AC power or 85% of the power demand charge threshold for DC power.

4.4 Demonstration Testing

- 4.4.1 Demonstration testing shall take place over six months with a minimum of 90 charges.
- 4.4.2 Charging shall be performed with completely random variables (StAR battery SOC, vehicle VEI, times, etc), as would be the case if the UUT was installed normally.
- 4.4.3 The power demand charge threshold shall be set to 20 kW, where possible. In the case that the power demand charge threshold is not configurable, an attempt shall be made to locate the unit such that the threshold value of the charger coincides with the transition power value between two utility demand charge rates.
- 4.4.4 Other operational configurations, such as TOU, customizable battery recharging schemes, etc., shall be implemented as determined by the Mandated Reviewer for a minimum of one week but not longer than one month.
- 4.4.5 Test data shall be collected during vehicle charging events and/or while the StAR battery is recharging. Other data recording conditions shall be decided by the Mandated Reviewer.

4.5 Test Reporting

This section provides guidance on the information to be presented on the testing outline in the previous sections. This section should not be viewed as comprehensive but rather as a general guidance.

4.5.1 Single Charge Test with and without StAR Battery Support

- 4.5.1.1 Graph of AC grid power, StAR battery power, and DC vehicle charge power over the duration of the vehicle charge and the subsequent StAR battery recharge.
- 4.5.1.2 Graph of AC power factor and AC grid power⁴ over the duration of the vehicle charge and the subsequent StAR battery recharge.
- 4.5.1.3 Calculate the StAR battery discharge resistance at 100% SOC (based on full charge or manufacture defined SOC) using Equation (1).

$$R = \frac{\Delta V}{\Delta I} = \frac{V_i - V_{30}}{I_{Dch}} \quad (1)$$

4.5.2 Consecutive Charges

⁴ This excludes power blended with the StAR battery in the case where the latter power is inverted and put onto the AC power line to assist with the vehicle charging power.

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- 4.5.2.1 Graph of AC grid power, StAR battery power, and DC vehicle charge power over the duration of all vehicle charges and the subsequent StAR battery recharge.
 - 4.5.2.2 Graph of AC power factor and AC grid power⁴ over the duration of the all vehicle charges and the subsequent StAR battery recharge.
 - 4.5.3 Demonstration
 - 4.5.3.1 Detail the ability of the UUT to charge at or below the power demand charge threshold, making sure to include the penalties seen from either the cost of power for exceeding, or the reduction in vehicle charging power for remaining at or below threshold.
 - 4.5.3.2 Detail the ability of the UUT to perform the operational configurations, compared to the set configuration, and how that operational configuration affected or changed the overall UUT performance.
 - 4.5.3.3 After each month of testing, calculate the StAR battery discharge resistance at 100% SOC (based on full charge or manufacturer-defined SOC) using Equation (1).

5 Glossary

APU: Auxiliary power unit. This is an engine coupled to a generator for the purpose of producing electricity. The electricity is normally used for propulsion purposes; however, in certain vehicles, the electricity can be used by off-board devices. If the latter capability exists, the testing described in this document is conducted

AVTE: Advanced Vehicle Testing and Evaluation

CECET: Center for Evaluation of Clean Energy Technology (CECET)

Charge-Depleting (CD) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is depleted (not continuously, but the trend is depletion) while the vehicle is driven. May be ESS-Only (i.e., the vehicle operates solely on energy from the ESS) or Blended CD (i.e., the vehicle operates on energy from both the ESS and the consumable fuel energy converter (CFEC)).

Charge-Sustaining (CS) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is maintained within a prescribed range by operation of a consumable fuel energy converter (CFEC).

Consumable Fuel Energy Converter (CFEC): An engine which consumes fuel to produce work (either electrical or mechanical).

Curb Weight: The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.

Effective Date: After a document has been reviewed and approved, the first date the procedure can be utilized in an official capacity.

Energy Storage System (ESS): A component or system of components that stores energy and for which its supply of energy is rechargeable by an electric motor-generator system, an off-vehicle energy source, or both. Examples of ESSs include batteries, capacitors, and electromechanical flywheels.

ESS-Only Mode: An operator selectable vehicle operating mode in which the CEFC is disabled and the vehicle operates solely on energy from the ESS.

Gradeability: The maximum percent grade which the vehicle can traverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward.

Initial Conditions: Conditions that must exist prior to an event occurring.

Initial State of Charge (SOC): ESS SOC at the beginning of a test.

Mandated Reviewer: The individual(s) responsible for the implementation of the AVTE program and of other advanced vehicle testing activities.

Prerequisites: Requirements that shall be met or resolved prior to an event occurring.

SAE: Society of Automotive Engineers

Shall: This word is used to indicate an item which requires adherence without deviation. 'Shall' is used to identify the binding requirements in a statement. A go or no-go criterion.

Should: This word is used to identify an item, which requires adherence if at all possible. 'Should' statements identify preferred conditions.

State of Charge (SOC): The ESS SOC is defined as the present capacity, (ampere-hours or watt-hours or miles), expressed as a percentage of the total available.

Test or Project Engineer: The individual(s) assigned responsibility for the conduct of any given test.

Test Mass (Weight): The mass [weight] of the vehicle as tested, including driver and all instrumentation

Tractive Force: The force available from the driving wheels at the driving wheel/ground interface.

Unit Under Test: This phrase is used as reference to any unit that could be tested by this Test Specification.

Vehicle Manufacturer: Entity that manufactured the test vehicle.

6 References

None